Semi-annual Eos Contract Report -- Report #36
Period: July 1 - December 31, 1994
Remote Sensing Group (RSG), Optical Sciences Center (OSC) at the University of Arizona
Principal Investigator: P. Slater
Contract Number: NAS5-31717
Report compiled by: K. Thome

Summary: Work by members of the RSG during the past six months consisted of Science Team support activities including presentations of papers by members of the group at IGARSS'94 and the Rome SPIE meeting, attendance at meetings related to MODIS and CERES calibration, delivering a prototype look-up-table for the atmospheric correction of ASTER data, and participation in a calibration round-robin. We continued improvements to our calibration facilities including receipt of a 40-inch spherical integrating source, testing a new laboratory reflectance standard, and characterizing our Optronic monochromator. Field work activities were continued with trips to White Sands in August and October. We took delivery of our mobile laboratory in November. Work continued on developing the BRDF and diffuse-to-global meters and improving our existing field equipment.

Introduction: This report contains twelve sections. The first ten sections present different aspects of work performed under our contract. If appropriate, each section covers five areas; task objective, work accomplished, data/analysis/interpretations, anticipated future actions, and problems/corrective actions. The ten sections are: 1) Science team support activities; 2) Cross-calibration radiometers; 3) Reflectomobile; 4) Mobile laboratory; 5) Shortwave infrared (SWIR) spectroradiometer; 6) Bi-directional reflectance distribution function (BRDF) meter; 7) Diffuse-to-global meter; 8) Calibration laboratory; 9) Algorithm and code development; and 10) Field experiments. The eleventh section contains information related to faculty, staff, and students, and the twelth section summarizes papers published, submitted, and in preparation.

Science Team Support Activities: This section refers to all work performed in support of MODIS and ASTER team activities as well as work performed for other sensor teams. Over the past six months this included the attendance at team and other related meetings and completing assigned action items.

ASTER Activities: At the end of July, P. Slater sent a message to eight of the key payload panel members emphasizing the loss to EOS that would occur if the US ASTER Science Team was disbanded. (This was proposed, in addition to approximately 18 other possibilities, to meet the $750M cut in the EOS budget.) The following extract summarizes the message: "Is NASA prepared to sacrifice the US ASTER Science Team to save $5M per annum, while paying for the space and cost of accommodating ASTER on the AM-1 platform, to get OPS-quality data and science results in return?"

Slater edited, revised and reformatted the Ono et al. paper titled "Preflight and in-flight calibration plan for ASTER" which is to be published in the Journal of Atmospheric and Oceanic Technology. There are five Japanese and four US ASTER team members who contributed to the paper. Slater, S. Biggar, K. Thome, D. Gellman and P. Spyak wrote a paper titled "In-flight radiometric calibration of ASTER by reference to well characterized scenes" for the EUROPTO/SPIE meeting in Rome.

On August 10 Thome met with R. Alley, B. Eng, A. Murray, M. Pniel, and C. Voge to discuss issues related to the atmospheric correction of ASTER. Thome completed the ASTER test site survey and returned it to A. Morrison of JPL

Slater attended the ASTER calibration plan review in Tokyo, Japan November 7-11. Slater and Thome attended the Joint ASTER Science Team Meeting in Kagoshima, Japan from November 14-18. Slater co-chaired the Radiometric Calibration Working Group meeting and presented the RSG's plans for field measurements to the Higher Level Data Products Working Group. Thome presented the current status of the VNIR-SWIR atmospheric correction and validation plans to the Atmospheric Correction Working Group. Slater, Thome, Arai, Fujisada, Kieffer, Palluconi, Ono, Sakuma, and Yamaguchi are preparing an invited paper titled: “Radiometric calibration of ASTER data” for submission to the Journal of Remote Sensing of Japan as part of a special issue on ASTER.

MODIS Activities: On July 1, Biggar and Slater met in Tucson with Ed Knight, an MCST representative who had visited SBRC earlier in the week with Harry Montgomery (MCST). The three discussed the latest developments on the MODIS project at SBRC, and the problem of stray light introduced by the scanning mirror, in particular. During the Payload Panel meeting at Landover, Maryland, Slater met with B. Guenther, P. Abel, and H. Montgomery to discuss the next step in responding to criticisms made by the MODIS Calibration Peer Review Panel. They decided to hold a meeting on September 22 and 23 at Goddard Space Flight Center to review the progress that MCST has made in the past five months in this regard. At this meeting, Slater, Guenther and other members of MCST discussed stray light, the agenda for the MODIS Science Team Meeting in October, and replies to the RFAs generated during the MODIS Cal Peer Review chaired by Skip Reber. Biggar and Slater attended the MCST meeting on October 11 and the

MODIS Science Team Meeting on October 12-14. Biggar provided written comments of the ATBD architecture to B. Guenther.

On the stray light issue, Spyak sent optical components scatter data to Jerry Godden at Physics Applications, Inc. (GSFC contractor) and performed a first-cut MODIS diffraction analysis. Spyak attended a MODIS stray light analysis meeting at BRO, Inc. in Tucson on October 31. Also in attendance were Godden, T. Ferguson and T. Kampe of SBRC, and B. Breault and D. Milsom of BRO, Inc. The group discussed the scatter model and the inputs to this model developed by BRO. Spyak received five action items as a result of this meeting. Spyak has since met with Breault to discuss the issue of stray light. Spyak researched and analyzed the wavelength scaling of measured BRDFs and the crossover of surface scatter and contamination scatter. Spyak has also requested a copy of the scan mirror data from Breault.

Other EOS Related Activities: Slater attended the EUROPTO/SPIE meeting in Rome, for which he was honorary chairman, and presented the paper on in-flight ASTER calibration mentioned above. Spyak attended the International Symposium on Spectral Sensing Research in San Diego, July 8-15. Biggar and Thome attended IGARSS'94 August 8-12 in Pasadena, Calif. Biggar co-chaired a session on sensor calibration and performance verification and presented a paper entitled "Solar-radiation-based absolute calibration of optical sensors: SeaWiFS and Daedalus 1268." Thome co-chaired a session on atmospheric correction of satellite data over land and presented two papers entitled "Proposed atmospheric correction for the solar reflective bands of the ASTER" and "Absolute radiometric calibration of Landsat-5 TM and the proposed calibration of the ASTER." On August 16 and 17, Thome attended a workshop on Techniques for Radiometric Cross-Calibration of Visible and IR Remote Sensing Instruments held at the EROS Data Center near Sioux Falls, South Dakota. Spyak served as a panel member for the CERES calibration peer review September 27-28 and attended the NIST IR calibration workshop December 6 - 7 in Washington. R. Parada and Slater prepared and submitted the second annual SeaWiFS report.

Slater met with two CSIRO scientists, Fred Prata in Melbourne and Jon Hunington in Sydney to discuss vicarious calibration activities in Japan. He also attended the CEOS meeting in Canberra and was asked to organize an atmospheric correction meeting in Europe as part of the EUROPTO/SPIE remote-sensing series in 1996. At the CEOS meeting he discussed international vicarious calibration activities and the use of solar-radiation-based calibration. With regard to the latter, he found that, at the same time that the RSG had calibrated SeaWiFS using solar-radiation-based calibration, SCARAB was also using a very similar approach for calibration in the solar-reflective range. Partly as a result of meetings with MCST, the ASTER calibration working group, and the above meetings in Australia, Slater and Biggar have written and submitted a paper titled

“Suggestions for calibration coefficient generation” for inclusion in the special issue on calibration of the Journal of Atmospheric and Oceanic Technology.

Cross-Calibration Radiometers: This section describes work to design, fabricate, test, and calibrate a set of preflight cross-calibration radiometers (CCRs). These radiometers are to cover the wavelength region from 400 to 14500 nm. To accomplish this, several separate radiometers will be constructed, each optimized for a specific portion of the spectrum. They will have very low stray light and polarization responses, exhibit sharp, well-defined fields of view and spectral response profiles, and be ultrastable with respect to temperature and time. The radiometers will be used to provide an important independent calibration and cross-calibration of the calibration facilities used by the Phase C/D contractors. The targeted completion date for all of the CCRs is the last quarter of calendar year 1995.

VNIR CCR: The objective of this project is to design and build a 400-900 nm cross-calibration radiometer, test this radiometer, and write control and data acquisition software. This radiometer will be compared to NIST-traceable standards of spectral irradiance using HALON targets. Biggar designed the radiometer with three silicon detectors in a "trap" configuration. Spectral selection is through interference filters and two precision apertures determine the throughput. Heating the detector assembly, filters, apertures, and amplifier to a stabilized temperature, a few degrees above ambient, provides thermal control of the system. A commercial datalogger digitizes the amplifier output and ancillary information such as detector temperature, and controls the amplifier gain through digital output ports. This datalogger sends the serial digital data to an MS-DOS compatible computer.

While in Pasadena for the IGARSS conference in August, Biggar and ASTER team member F. Sakuma of NRLM performed cross-calibration measurements on the MISR and AVIRIS spherical integrating sources, the AVIRIS lamp and panel, and filters at JPL. Biggar began a more detailed examination of these data using the SeaWiFS GSFC sphere as the standard. He spent the week of September 26-30 at San Diego State University for SIRREX 3 making measurements of several spherical integrating sources including the CHORS sphere overnight. Measurements were also made on two of our calibrated lamps the week before. The new HP3458A was used to check shunts and other voltmeters. Biggar performed a preliminary data reduction and emailed the results to J. Mueller of CHORS and C. Johnson of NIST. He also compared recent measurements of the six-inch spherical integrating source with the NIST measurements made during SIRREX-3.

Biggar modified the VNIR transfer radiometer code to control the six-inch spherical integrating source and to use the new HP3458A voltmeter for measuring the radiometer output.

He measured the radiometer's FOV and out-of-band response using a collimator and the recently received 40-inch spherical integrating source. He found the size-of-source effect to be less than 1% using our 40-inch spherical-integrating source and changing the source aperture from 2 to 16 inches. The response is also down 4 orders of magnitude at about 4 degrees off axis using a collimated point source. Biggar modified the radiometer's software to monitor temperature and shut down the heater if the temperature exceeds a critical value. In October, Biggar sent drawings of the VNIR transfer radiometer aperture to NIST and is awaiting cost estimates related to NIST measurements of the aperture. B. Nelson has completed drawings related to improving/redoing the electronics and mechanical pieces for the radiometer and ordered and received the new circuit boards for the radiometer, as well as many of the other parts.

SWIR CCR: The objective of this project is to design and build a 1100- to 2500-nm cross-calibration radiometer, test this radiometer, and write control and data acquisition software. This radiometer will be compared to NIST-traceable standards of spectral irradiance and HALON targets.

Spyak continued his review of the SWIR radiometer design. He identified possible detector types and ASTER and MODIS related requirements for the SWIR radiometer and is investigating possible vendors. After studying detector types, he has decided on two candidates. The first is the bolometer described in the next section. The second is InSb. Spyak is currently investigated these two options and will make a decision during the next reporting period.

TIR CCR: The objective of this project is to design and build cross-calibration radiometers to cover the 3000- to 14500-nm spectral region, test these radiometers, and write control and data acquisition software. In the last semi-annual report we stated that "during the March budget exercise it was decided not to construct thermal radiometers that would operate in thermal vacuum because budget cuts will not allow adequate radiometers to be built. After further budget studies, it was determined that no thermal cross-calibration radiometer will be built." Since then, it was decided to attempt to construct a field-compatible TIR radiometer which could also operate as a transfer radiometer. This radiometer will be designed for precision only.

Spyak developed spreadsheets for signal, general design, and detector analyses for the radiometer. He investigated pyroelectric, HgCdTe, and bolometer detectors. Biggar and Spyak met with E. Dereniak of the Optical Sciences Center to discuss detector selection for TIR and SWIR applications. Dereniak agreed with the detector selections (InSb for SWIR and HgCdTe for TIR). However, HgCdTe is not linear, and not always repeatable because its properties can change with time. Thus, we are hesitant to use HgCdTe. Dereniak highly recommended we build two TIR radiometers, one for the lab and one for the field, and suggested the lab instrument use a liquid-helium-cooled bolometer covering the range from 1-15 µm. Spyak is currently investigating this.

Thome developed software for analysis of the atmospheric effects in the lab using MODTRAN. Spyak is using this software to investigate atmospheric effects on our laboratory measurements and in particular, effects on our transfer radiometer measurements.

Reflectomobile: The task objective is to design a vehicle and instrument package to perform field-surface-reflectance measurements more accurately, efficiently and repeatably with only one person. In the past, people have carried yokes which extend the radiometers away from the walker's body to reduce shadow and other problems. This method requires the involvement of at least three people, takes about 40 minutes to cover a 0.02 km^2 site, and depends on the ability of the walker to orient the radiometer correctly. Construction of the reflectomobile is complete but use of the device at White Sands Missile Range has been problematic because of the tracks left by its use. We collected data to investigate the effects on these tracks on the reflectance of our test site. We hope to have the results of this investigation within the next six-month reporting period.

Mobile Laboratory: The objective of this task is to design a mobile laboratory for 1) storage and transportation of equipment; 2) electricity (AC and DC) for equipment; and 3) shelter from the sun, heat, and cold for computers and people during measurements and for all of our equipment overnight at experiment sites.

Biggar met with the trailer vendor representative to ensure we get what we need from Wells Cargo. Nelson received the information necessary to get the hitch for the trailer on the truck installed and had the hitch installed. The university took delivery of the trailer in November. During the next reporting period we will acquire the generators for the trailer and begin testing its use under field conditions.

SWIR spectroradiometer: The objective of this task is to design and construct an instrument to measure surface reflectance in the SWIR region of the spectrum. When our contract began, M. Smith had already designed and built the prototype.

Because of the device's size and problems with its use in the field, we recently acquired a spectrometer from Analytical Spectral Devices which covers the 400- to 2500-nm spectral range. C. Gustafson has begun evaluating the device and determined several problems with the system. The extension fiber optic is contaminated, the fiber optic link to the field of view defining optics required modification, and the system does not allow the user to manually select an integration time. There have also been numerous problems with the data acquisition software. Data from the instrument using the blacklab indicate there may be a signal-to-noise problem with the spectrometer in the blacklab. These problems have prompted us to investigate the use of the original SWIR spectroradiometer for use in the blacklab.

During the next six-month period, we will evaluate the current status of the SWIR spectroradiometer and determine if it should be redesigned using the current detector and grating as the basis of the design, or if the system can simply be modified with upgraded electronics to make it operational again. Thome will also begin investigating its use as a solar radiometer to extend our current atmospheric transmittance measurements into the SWIR.

BRDF Meter: The objective for this task is to design and construct a device, and develop software for measuring the directional reflectance and inferring the bi-directional reflectance distribution function of the ground. The basic design incorporates a fisheye lens and a CCD-array detector.

M. Brownlee ordered and received the interference filters for the BRDF meter. She developed mounts and an aperture stop to allow the spectral transmittance of these filters to be measured using our Optronic monochromator. Brownlee and Nelson determined the requirements for a filter wheel to allow the filters to be removed without disassembling the lens. Brownlee ordered and received the carrying cases for the BRDF meter equipment. She tested the gasket seal of the liquid chiller to determine if it is possible to transport the chiller with liquid. Brownlee designed a new mount for the camera to include a tip-tilt table and rotation stage. The tip-tilt table will be used to level the system and the rotation stage will offer azimuthal rotation. The new tripod mount for the camera is about 50% completed. The tip-tilt table mounting plates were built and are being tested. She ordered and received a custom rotation stage and worked on an extension arm design for the system.

Mounts for using the system's 10-inch x 10-inch reflectance panels (2% and 50% reflectance) in the blacklab were designed and the drawings given to the OSC machine shop. Brownlee designed storage and carrying cases for the panels. The designs call for the panels to be held vertically with an air gap between the two to prevent damage to the Spectralon surfaces. The storage unit is then mounted in a carrying case for transporting the panels. The designs have been submitted to the OSC machine shop.

Brownlee began investigating the radiative transfer code for use in the BRDF data retrieval and used the code to examine the effects of specular reflectance for cases of low solar elevation angles. She is developing IDL routines for displaying BRDF data.

Future work includes Brownlee determining the tolerances needed for the measurement of surface BRDF for satellite-sensor calibration using typical White Sands data. She will complete the extension arm for the BRDF camera, measure the spectral responses of the filters, and modify the radiative transfer code to account for 3-dimensional surface scattering. She will begin an error analysis for validation of BRDF measurements, and determine a flat-fielding calibration method using the 40-inch spherical integrating source.

Diffuse-to-global meter: The objective of this task is to design and build an instrument to collect diffuse-to-global irradiance data. By comparing the diffuse downwelling irradiance to the global (direct plus diffuse), an improvement to the atmospheric correction may be made which reduces the uncertainty of the reflectance-based method. Currently global irradiance data are collected using a radiometer viewing a reflectance panel and diffuse data are collected by manually positioning a parasol to shade the panel. The diffuse-to-global meter will collect these data automatically and more repeatably.

B. Crowther developed calibration scenarios using our radiative transfer code to model expected results diffuse/global meter measurements. As a result of this preliminary modeling, Crowther ordered the LI-COR spectrometer to use as the sensor for the instrument. Once it arrives, he will characterize the optical fiber from the spherical-integrating source receptor and more fully design the receptor.

Calibration Laboratory: The objective of this project is to develop a calibration laboratory that will provide the necessary high-radiometric-accuracy standards for 1) the cross-calibration radiometers and 2) the field and aircraft radiometers needed for preflight algorithm and code validation and the actual in-flight calibration of the EOS multispectral imaging sensors beyond 1998.

Using the Optronic monochromator, Biggar attempted several times to measure the filter transmittance of the interference filters in preparation for the MISR and AVIRIS cross calibration at JPL in early August. Spyak and Biggar obtained a new controller board for the monochromator chopper and installed it. They also continued their characterization of the monochromator and prepared and sent a letter to Optronic detailing the numerous difficulties we have had with the system. Spyak ordered a diffuse reflectance attachment and software for the monochromator, and upgraded the current software. The filter wheel for the system failed again in September while J. Lamarr was making system characterization measurements. The unit was returned to the manufacturer for repair. Measurements made by Lamarr before the unit malfunctioned indicate significant differences in results from measurements made on different days. He also prepared and sent a report on the operation of our monochromator to Optronic to assist them in determining the cause of the system's malfunction. Optronic has since found the problem(s). It appears that whenever there is a change in wavelength, grating or filter, there is a power drain throughout the system which causes the problems we see. To resolve this problem Optronic added additional grounding wires in the 5-V power supply, isolated boards, rewired cables, and installed an independent power supply on the wavelength drive. They also tested for static problems. The unit is to be shipped to us on Jan. 2 and should arrive here on Jan. 4.

Spyak and C. Lansard compared HALON and ALGOFLON reflectance standards for our blacklab calibration work and found ALGOFLON to be a good replacement for HALON since it is slightly more lambertian, has no specular component, and its reflectance is spectrally flat over the 450-1040-nm wavelength region. Some of the results from this work are presented in Figures 1 and 2. Figure 1 shows the close agreement in the directional reflectance factor between HALON and ALGOFLON while Figure 2 shows the variation in directional reflectance factor as a function of wavelength. Hemispherical reflectance measurements still must be made and these measurements will most likely be done by NIST and RSG. Spyak and Nelson designed new holders to accommodate NIST's facility and these holders are currently being fabricated. Lansard also investigated the repeatability of our measurements in the blacklab. LaMarr recently repeated these measurements and found no significant effects on the panel calibrations due to dismounting and mounting the radiometer and changing the source. These data also agree with data collected this past summer by Lansard with the same reflectance sample, implying that the lifetime of an ALGOFLON sample is on the order of several months.

LaMarr and Spyak began characterizing blacklab stray light by examining the effects of baffling the incident light, changing the aperture-to-source distance, and surrounding the reference ALGOFLON panel with a barium sulfate panel. Of the three, the surrounding barium sulfate panel had the largest effect. They also found the edge of the radiometer filter holder to be a significant source of stray light and the radiometer used for reflectance panel calibrations has a field of view larger than previously believed.

Biggar, LaMarr and Spyak calibrated the helicopter Exotech radiometer used in the above described White Sands trip and Spyak documented the procedure. LaMarr and Spyak determined that our Spectralon reflectance panel calibrations are orientation dependent because of gaps between the individual Spectralon pieces which make up the panel. They are currently examining solutions to this problem. Gustafson, LaMarr and Spyak calibrated the panels used in the October White Sands experiment and supplied the results to Thome. Gustafson prepared a preliminary user's manual for the preparation of blacklab reflectance reference samples.

Gustafson and LaMarr constructed apertures for the 40-inch SIS and assisted Biggar in his transfer-radiometer measurements of the sphere. LaMarr instructed Gustafson on the operation of the Optronic monochromator and Lansard showed Gustafson and LaMarr how to press reflectance samples.

Spyak ordered and received a calibrated weight set for calibrating the scale used in creating the HALON/ALGOFLON reflectance standards. He ordered and received a shutter to automate our blacklab dark measurements and purchased additional accessories for ALGOFLON panel making. Biggar ordered a filter wheel motor/translator for the facility, and Nelson and V. Sinclair began designing new baffle plates for the blacklab wall and submitted the drawings to the OSC machine shop. Spyak ordered a 250-370 K blackbody source and investigated humidity and temperature sensors for the laboratory. LaMarr investigated sources for purchasing a water deionization system, microscope, and infrared polarizers. A deionizing system was ordered and received. Spyak ordered an optical breadboard to mount on the blacklab table to simplify mounting instruments and sources in the blacklab. He and Nelson completed drawings for the new ALGOFLON sample holders and pressing apparatus and submitted them to the OSC machine shop. Spyak ordered replacement interference filters for the radiometer used in the reflectance panel calibrations, and ordered replacement lamps for the blacklab. Half of the filters have been received. Spyak received the carbon dioxide jet spray cleaning apparatus and ordered and received the ZEMAX-EE lens design software.

Spyak ordered a laminar flow clean bench, an electrically calibrated pyroelectric radiometer, and a barometer to replace our field version which is to go into the calibration laboratory. Biggar ordered a kinematic FEL lamp socket and alignment jig and Spyak ordered equipment for cleaning optics in the calibration laboratory. Biggar modified our blacklab software to enable it to use active lamp control and to allow for more viewing geometries. Biggar and Spyak ordered and received a lock-in amplifier to upgrade the amplifier currently being used and ordered an received a chopper for use with the amplifier. Spyak received the NIST SRM filters for calibrating the spectroradiometer system.

Algorithm and Code Development: Currently, several algorithms exist to perform our calibration work. The RSG has applied these algorithms as FORTRAN programs which are neither user friendly nor efficiently linked together into a single package. The task objective is to convert these existing codes into ANSI standard C in a user-friendly package with rules-based decision making in the package. The group is now also involved in the atmospheric correction of ASTER data in the solar-reflective portion of the spectrum

Thome completed revisions to the data dictionary for the atmospheric correction of ASTER and sent it to B. Eng of JPL. Thome examined the DEM requirements for the atmospheric correction and sent an email message summarizing the requirements to F. Palluconi of JPL. He began evaluating imagery data for use as test data and selected a Landsat scene from Maricopa Agricultural Center as part of the test data set. Work on the prototype look-up table included specifying the parameters which will be used to generate it and preliminary work on the format of the table. The prototype table was delivered to JPL the first week of November. Thome received and reviewed ASTER input dependency information for the VNIR-SWIR atmospheric correction from G. Geller of JPL. As a result of this, Thome contacted D. Diner of JPL via email regarding the status of the MISR aerosol data products and reviewed the MISR aerosol retrieval ATBD.

Field Experiments: The objectives of the field experiments are to test new equipment, determine needed improvements, test retrieval algorithms and code, and monitor existing satellites in much the same way as we shall for EOS sensors.

Thome and Parada travelled to Lake Tahoe, July 6-9 to look for possible locations for SeaWiFS field work. Biggar and Parada met with the Optical Sciences Center mechanical engineering personnel so they could begin the aircraft mount for the Lake Tahoe experiment. Parada submitted the aircraft mount specifications for the SeaWiFS calibration work to the OSC mechanics shop.

K. Scott and Spyak prepared for the group's August trip to White Sands for SPOT-3 calibration. Biggar, C. Grotbeck, Nelson, Scott, Sinclair, Slater, and Spyak travelled to White Sands August 16-19 to test data retrieval methods in addition to performing SPOT-3 calibration work. The group was also accompanied by T. Mitchell from the USDA and several French visitors representing CNES. Because of range closures and weather, no useful data were collected, but the group was able to test the new video camera and yoke design.

Nelson investigated SMPTE code generators, character generators, and frame grabbers for the video system. Nelson began breadboarding the sample and hold, Biggar ordered a Sun frame grabber, and Nelson completed designs for the new MMR yoke which were to be ready for the October WSMR trip. Spyak ordered a chopper for the auto-tracking solar radiometer and a fisheye lens for all-sky pictures. Biggar ordered additional field data loggers and radiometers.

Thome made plans for a trip in early October to White Sands to perform a calibration of Landsat-5 and a possible cross-calibration attempt with SPOT-3. On October 7, Biggar, C. Deschapelles, Gustafson, LaMarr, Laumann, Spyak, and Thome travelled to White Sands. Data were collected on October 8 in conjunction with an overpass of Landsat-5, including helicopter-based radiometer measurements of the site. Data were also collected on October 9 in conjunction with a SPOT-3 overpass at near-nadir. This trip marked the initial use of the video camera as part of the helicopter acquisition, the Cimel solar radiometer, and a new MMR yoke. Preliminary examination of the data indicate both days were successful except an error in the setup of the Cimel system prevented usable data from being collected. Thome processed the data from the SPOT-3 calibration at White Sands and began work on the Landsat data.

Slater travelled to Nevada October 26 and 27 to examine possible vicarious calibration test sites at Lunar Lake and Railroad Valley. Biggar and Laumann worked on the solar aureole camera to improve its reliability under cold weather conditions. Gustafson prepared a shipping case for the ten- and three-channel solar radiometers and began the process of permanently labelling all such cases. She and Deschapelles installed the Cimel solar radiometer on the roof of the Optical Sciences Center on the University of Arizona campus and began collecting data coincident with the Reagan 10-band solar radiometer but difficulties with the Cimel have been encountered because of a breakdown in the solar panel connections to the system. Gustafson prepared a carrying case for the Cimel.

Faculty, staff, and students: The personnel presently associated with the RSG are as follows. Faculty: Biggar, Slater, Spyak, and Thome. Staff: Burkhart, Kingston, Nelson, and Recker. Students: Brownlee* (Ph.D.), Crowther* (Ph.D.), Deschapelles (MS), Gustafson (Ph.D.), LaMarr (Ph.D.), Parada* (Pd.D.), Scott* (Ph.D.), and Walker* (Ph.D.). Those with an asterisk following their names have passed the Ph.D. Preliminary Examination and are mainly working on their Ph.D. research. Brownlee and Crowther have NASA Fellowships under the Graduate Student Researchers Program, Parada has a NASA Global Change Fellowship and Deschapelles has a Fellowship from the US Government. Walker is self-supported, leaving three graduate students supported by this and other contracts. Grotbeck successfully defended his

Ph.D. titled “Solar aureole instrumentation and inversion techniques for aerosol studies” in October 1994. He also had a NASA Global Change Fellowship. He has gone to work at Sandia National Laboratory on remote-sensing related programs. Lansard was a visiting French student who came to our group to work on the practical training portion of her degree at the Ecole Nationale Superieure de Physique de Strasbourg

Burkhart and Kingston are new additions. Burkhart comes from the OSC Machine Shop and is working on several mechanical improvements to existing laboratory and field equipment. (He replaces Sinclair.) Kingston, who is shared half time with another OSC research group, will be working on computer-instrument interfacing and network management.

Thome was promoted to Assistant Professor of Optical Sciences in August 1994. He presented the graduate level course “Fundamentals of Remote Sensing” during the Fall 1994 semester.

Publications

During the past six months the following papers were published:

Smith and Biggar. “Calibration and performance evaluation of a portable shortwave infrared (1.05 to 2.45 µm) spectrometer,” *Optical Engineering*, **33**:11:3781-3792, Nov. 1994.

Biggar, Slater, and Gellman. "Uncertainties in the in-flight calibration of sensors with reference to measured ground sites in the 0.4 to 1.1 micrometer range," *Remote Sens. of Environ.*, **48**:245-252, 1994.

Thome, Smith, Palmer, and Reagan. "Three-channel solar radiometer for determining atmospheric columnar water vapor," *Appl. Optics*, **33**:5811-5819, 1994.

Herman, Ben-David, and Thome. "Numerical technique for solving the radiative transfer equation for a spherical-shell atmosphere," *Appl. Optics*, **33**:1760-1770, 1994.

Biggar, Slater, Thome Holmes, Barnes. "Preflight solar-based calibration of SeaWiFS," SeaWiFS Technical Report Series (1994).

McClain, Fraser, McLean, Darzi, Firestone, Patt, Schieber, Woodward, Mattoo, Biggar, Slater, Thome, Holmes, Barnes and Voss. Volume 19, "Case studies for SeaWiFS calibration and validation, Part 2", NASA Technical Memorandum 104566, August 1994.

During the past six months the following papers were submitted or presented:

Slater, Biggar, Thome, Gellman, and Spyak. “Vicarious radiometric calibration of EOS sensors” submitted for publication in the special calibration issue of the Journal of Atmospheric and Oceanic Technology.

Slater and Biggar. “Suggestions for calibration coefficient generation” submitted for publication in the special calibration issue of the Journal of Atmospheric and Oceanic Technology.

Slater, Biggar, Thome, Gellman and Spyak. “The in-flight radiometric calibration of ASTER by reference to well-characterized scenes,” Presented at the EUROPTO/SPIE meeting in Rome in September, 1994. To be published in the conference proceedings.

Biggar, Thome, Slater, Balick, and Golanics. "Solar-radiation-based absolute calibration of optical sensors: SeaWiFS and a Daedalus 1268," *International Geoscience and Remote Sensing Symposium*, Pasadena, pp. 1992-1995, 1994.

Gellman, Biggar, Dinguirard, Henry, Moran, Thome, and Slater. "Review of SPOT-1 and -2 calibrations at White Sands from launch to 1993," accepted for publication in *Photogrammetric Eng. and Rem. Sens.*

Thome. "Proposed atmospheric correction for the solar-reflective bands of the Advanced Spaceborne Thermal Emission and Reflection Radiometer," *International Geoscience and Remote Sensing Symposium*, Pasadena, pp. 202-204, 1994.

Thome, Biggar, Gellman, and Slater. "Absolute-radiometric calibration of Landsat-5 Thematic Mapper and the proposed calibration of the Advance Spaceborne Thermal Emission and Reflection Radiometer," *International Geoscience and Remote Sensing Symposium*, Pasadena, pp. 2295-2297, 1994.

Qi, Cabot, Moran, Dedieu, and Thome. "Biophysical parameter retrievals using bidirectional measurements," *International Geoscience and Remote Sensing Symposium*, Pasadena, pp. 1816-1818, 1994.

The following papers are in preparation:

Ono, Sakuma, Arai, Yamaguchi, Fujisada, Slater, Thome, Palluconi, and Kieffer. "Preflight and in-flight calibration plan for ASTER" to be submitted for a special calibration issue of the Journal of Atmospheric and Oceanic Technology.

Grotbeck, Santer, Biggar, and Slater. "Solar aureole and optical depth inversion techniques for atmospheric radiative transfer calculations" to be submitted to Remote Sensing of the Environment.

Grotbeck, Biggar, Santer, and Slater. "Solar aureole instrumentation for aerosol studies" to be submitted to Remote Sensing of the Environment.

Slater, Thome, Arai, Fujisada, Kieffer, Palluconi, Ono, Sakuma, and Yamaguchi. "Radiometric Calibration of ASTER data" invited paper for the special issue on ASTER in the Journal of Remote Sensing of Japan.

Thome, Biggar, Slater, Spyak, Gellman, Moran, and Jackson. "In-flight radiometric calibration of Landsat-5 Thematic Mapper from 1984 to present."

Spyak, Lansard, Barnes. "A comparison of the reflectance properties of two reflectance-standard materials."